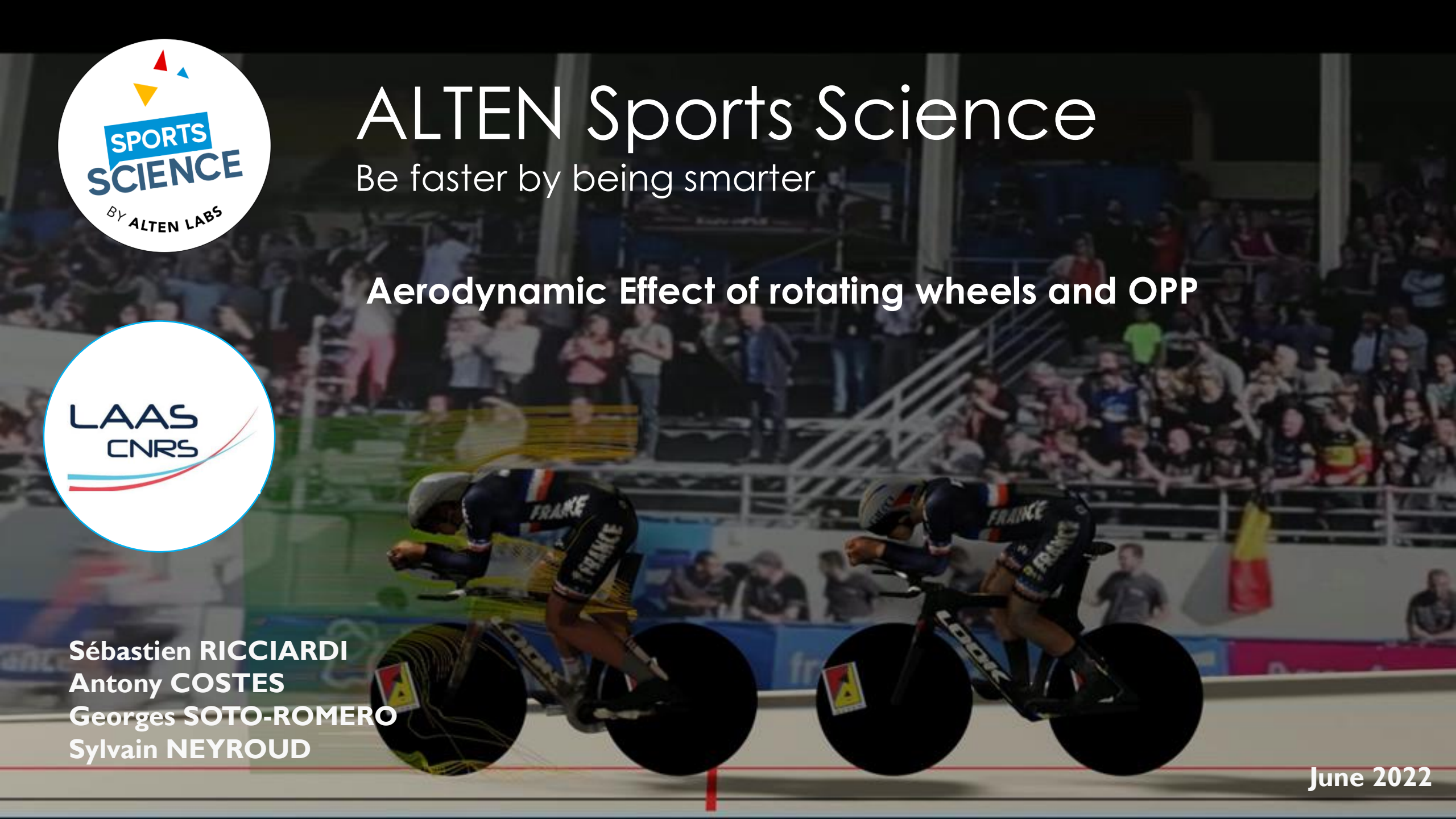
ALTEN Sports Science

Be faster by being smarter

Aerodynamic Effect of rotating wheels and OPP



Sébastien RICCIARDI
Antony COSTES
Georges SOTO-ROMERO
Sylvain NEYROUD

June 2022

ALTEN Sports Science

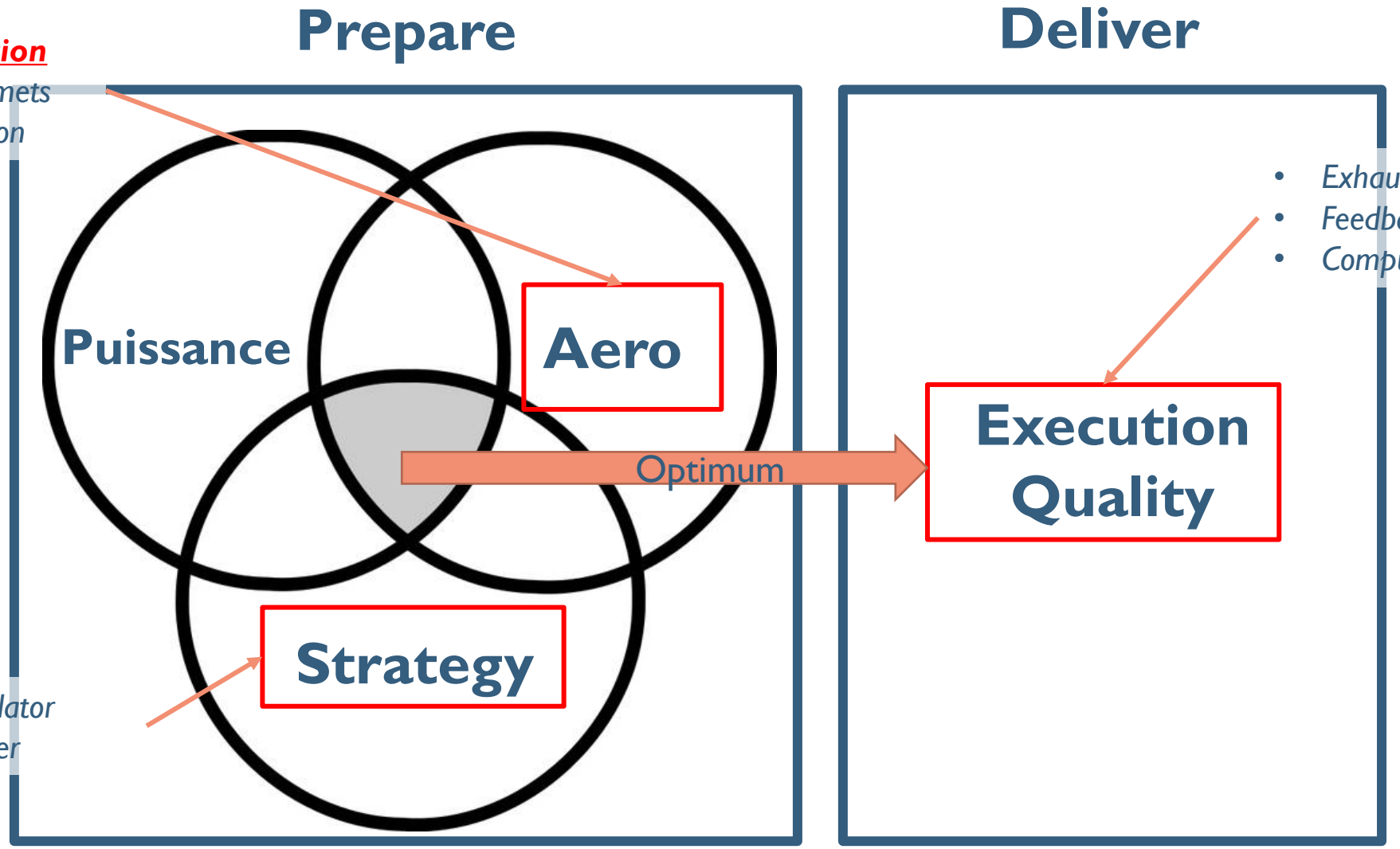
University
-
Science

R&D
Private
Company
-
Science for
Results

Professional
Teams
-
Practical
Results

Performance pillars in cycling

- ***Aero Optimisation***
- *Individualized helmets*
- *Position degradation*

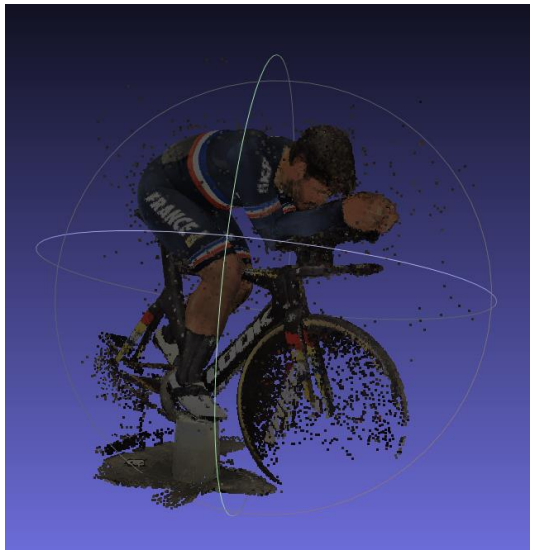


- *Exhaustion Prediction*
- *Feedback Tool*
- *Computer Vision*

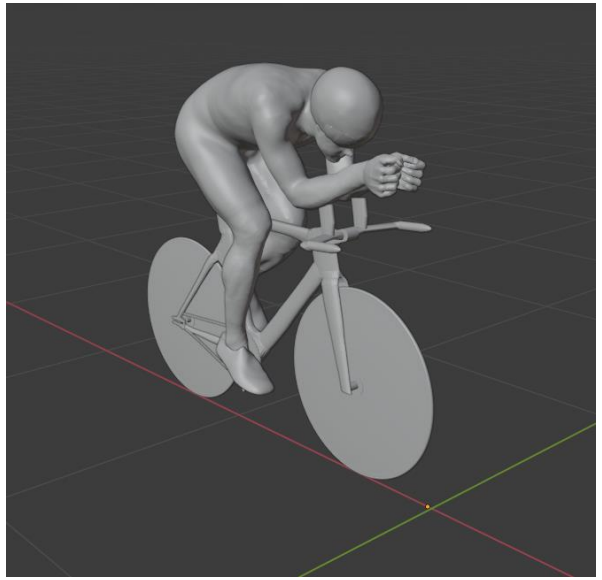
- *Track Cycling Simulator*
- *Time-Trial Optimizer*

End-to-end 3D Scan to CFD analysis

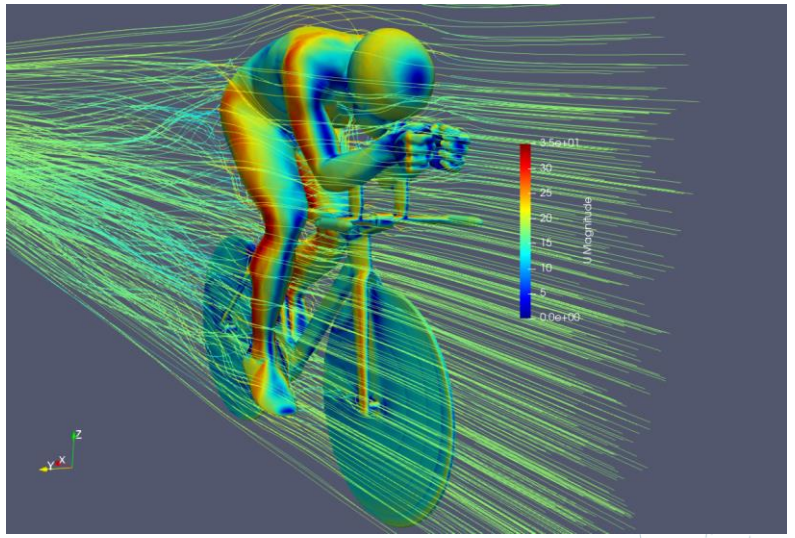
I. 3D Scan



II. Point cloud

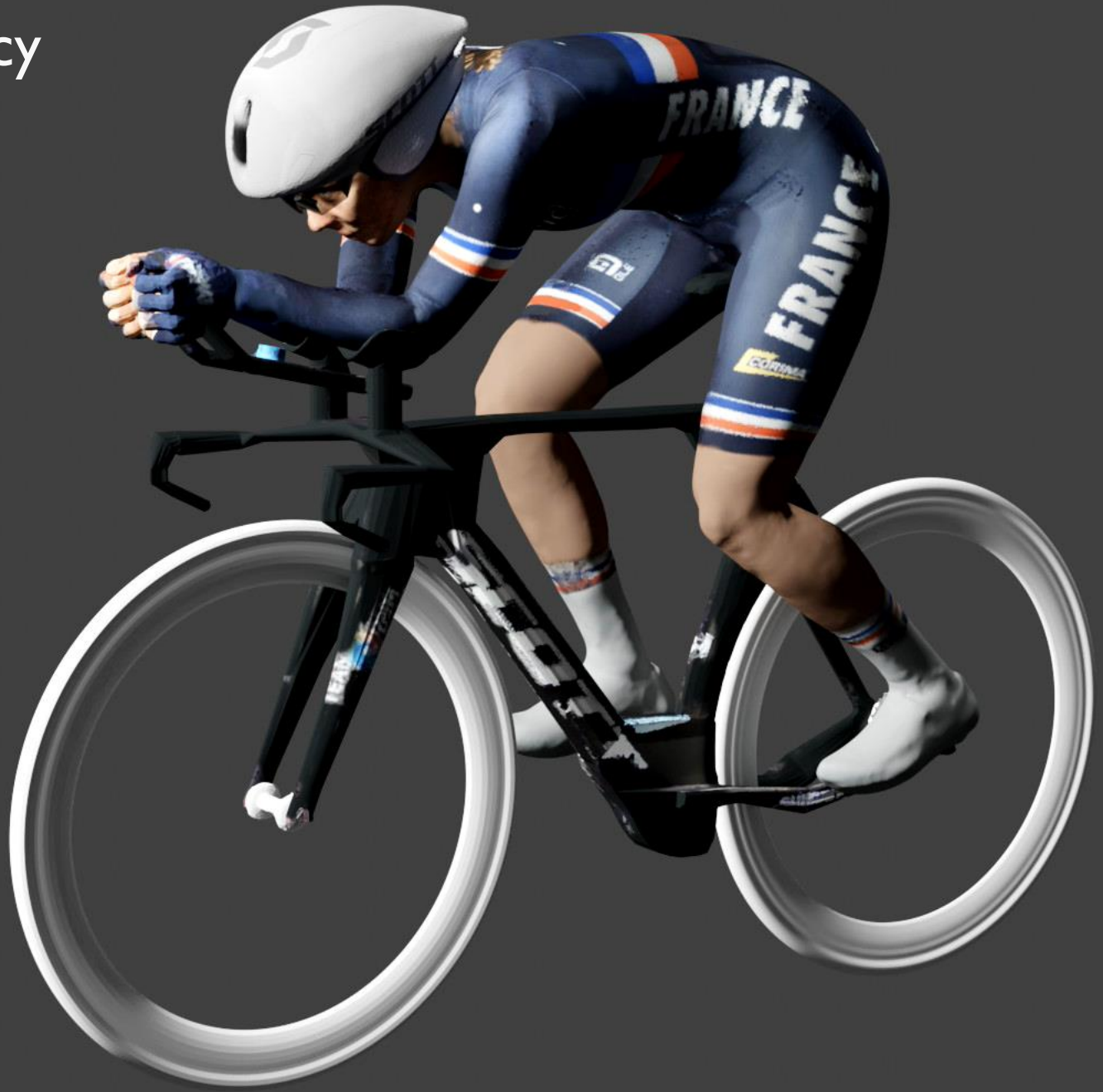


III. Reconstruction + retro-engineering +



IV. CFD Study & Optimisation

High Model accuracy

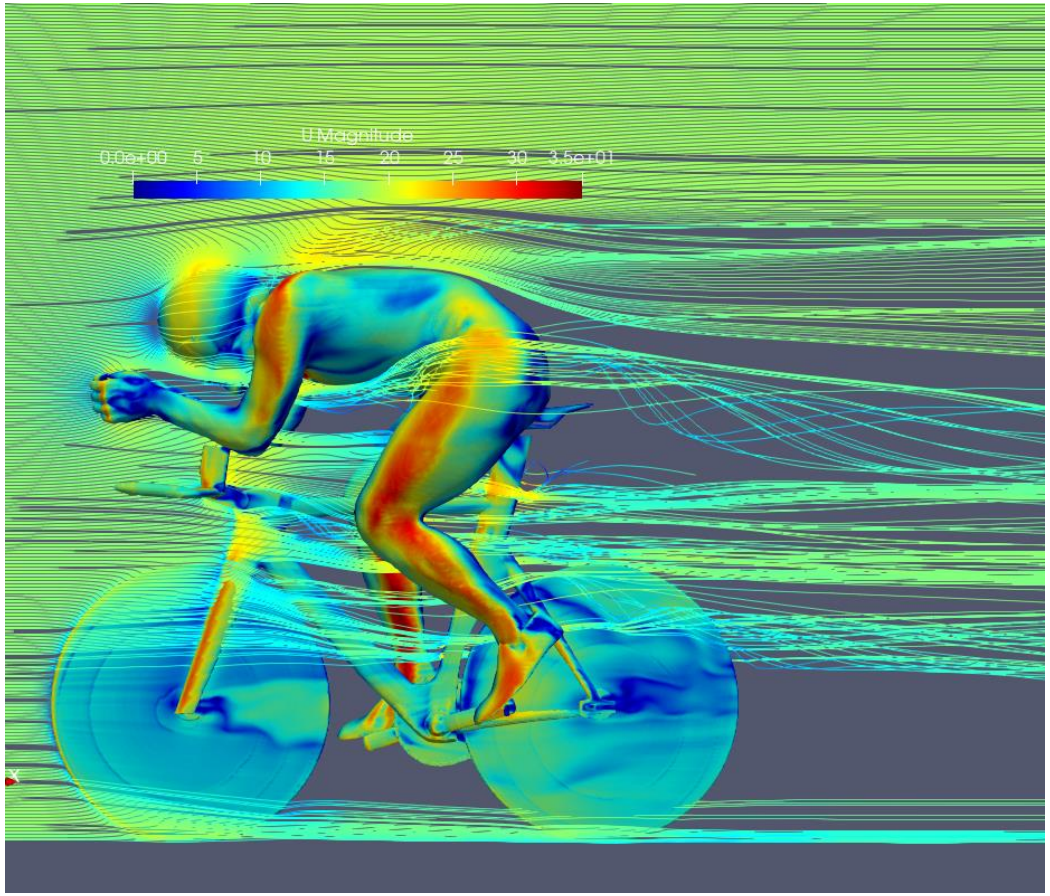


SPORTS SCIENCE BY ALTEN LABS

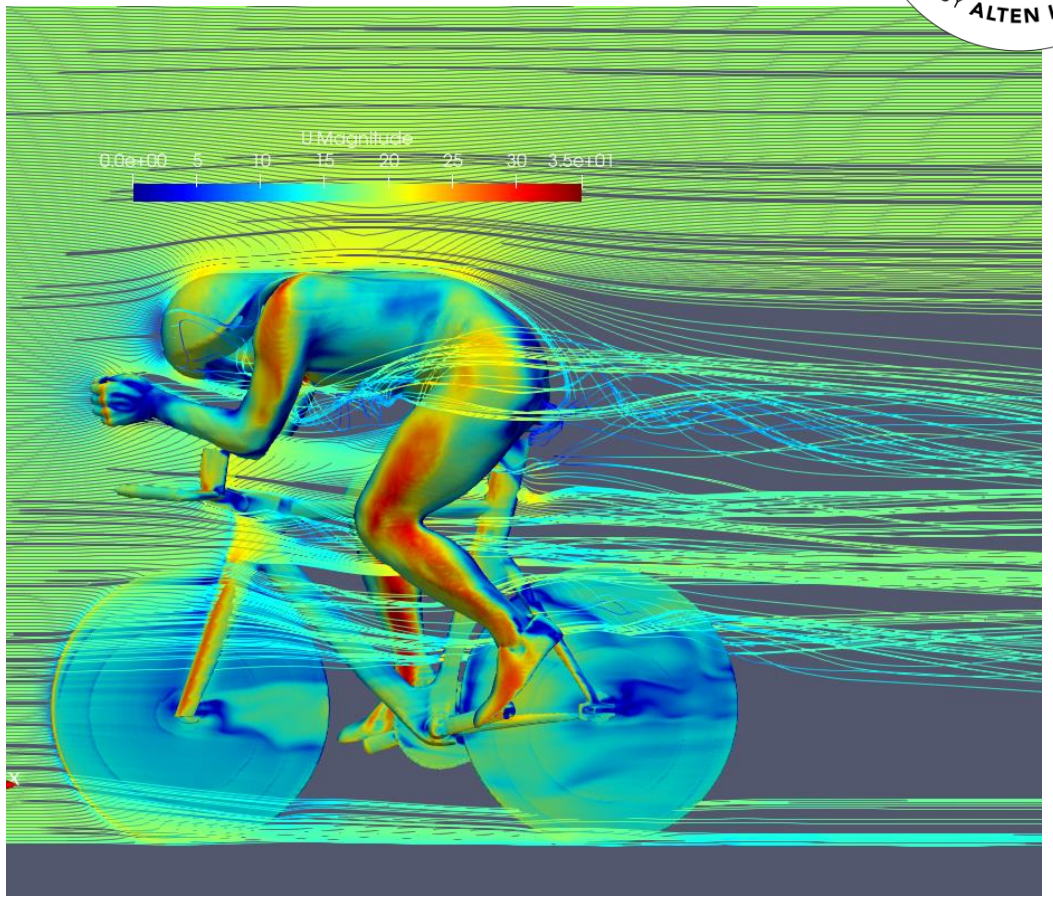
LAAS CNRS

FÉDÉRATION FRANÇAISE DE CYCLISME

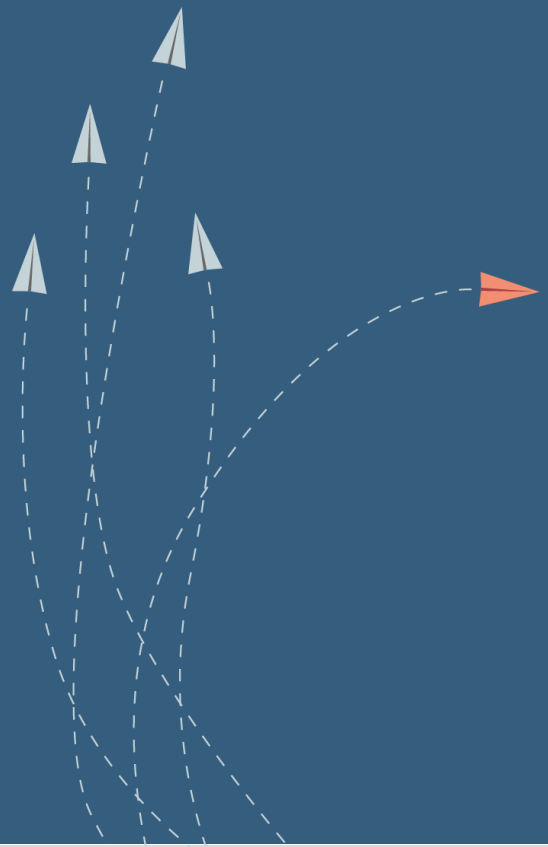
Helmets testing



Avant



Après



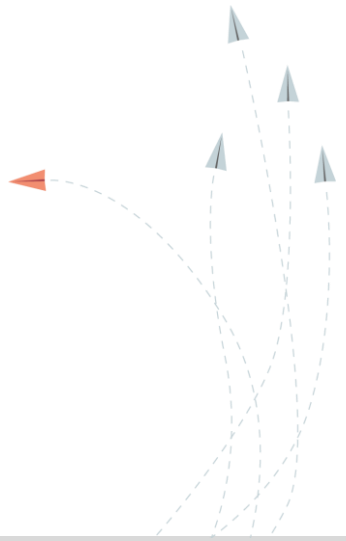
The study

What is the OPP ?

OPP = Over-Pressure Push

Over-Pressure Push Values in Litterature

- Blocken et al. (2013) => CFD : 2.6%
- Defraeye et al. (2014) => CFD : 3%
- Barry et al. (2015) => Wind tunnel : 5%
- Malizia (2020) :
  - CdA +39% for an isolated rotating wheel
  - CdA +3.5% higher for a full cyclist with wheels rotation compared to static ones.
- How can you reconciliate all these ?

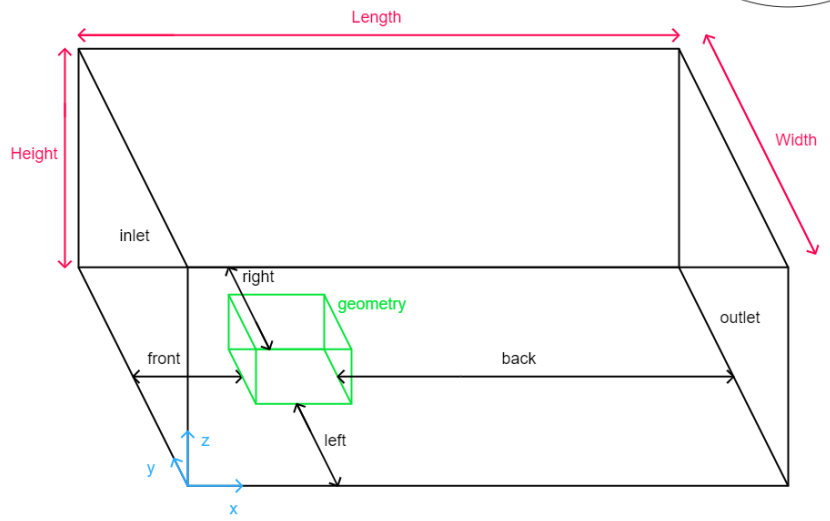


Model

- RANS
- k-omega SST turbulence model

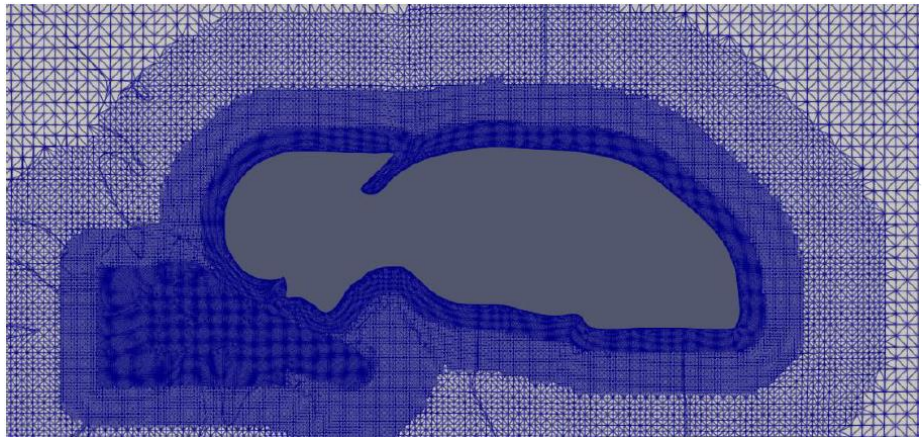
- Domain size :
  - 5L upstream, left and right
  - 6L above
  - 15L downstream

- Boundary conditions
  - Inlet : speed of 18m/s, turbulence intensity of 1%.
  - Ground : no-slip condition
  - Cyclist Body : no-slip condition
  - Outlet : zero-static pressure
  - Other walls : zero Gradient pressure



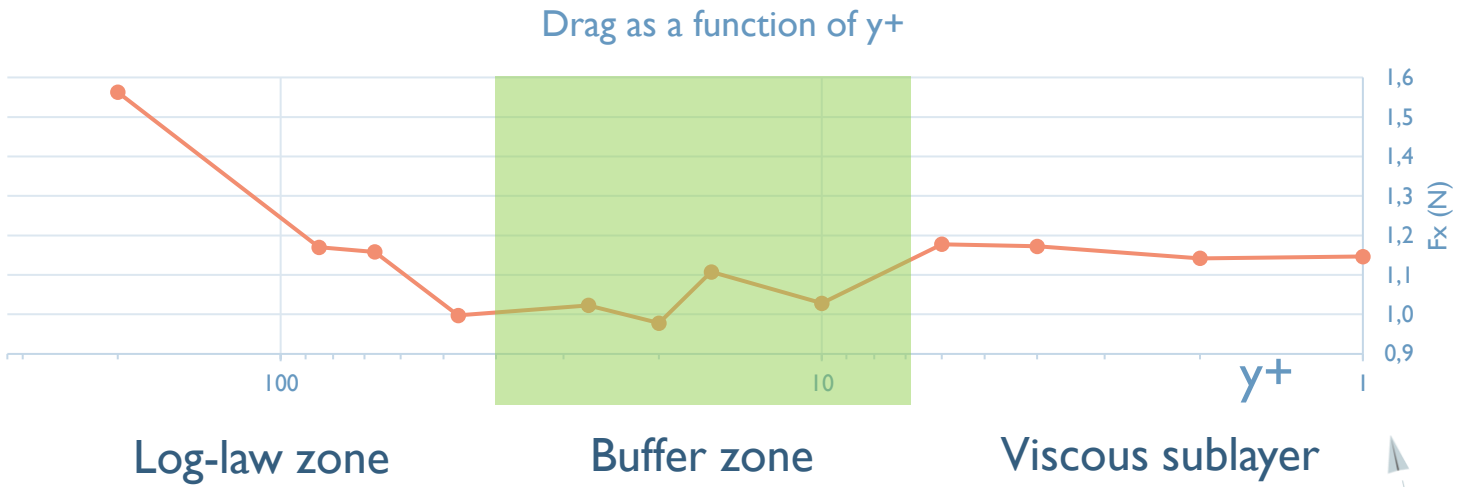
Grid convergence study

- Upper part of the body with no bike
- 5 m/s
- y+ from 300 down to 1



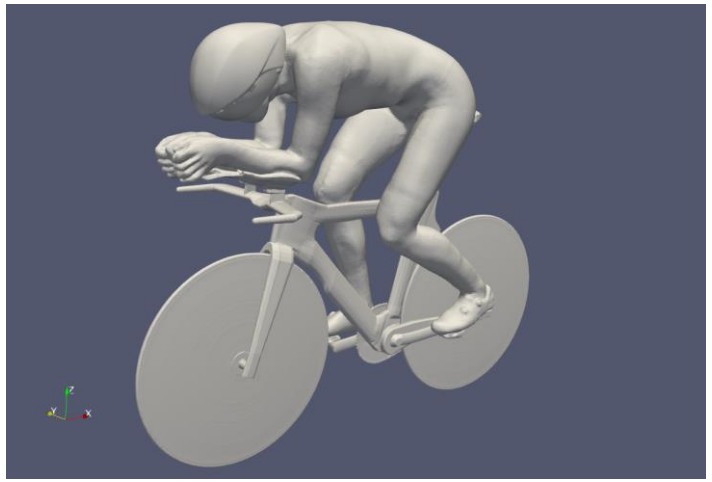
Grid convergence study (2)

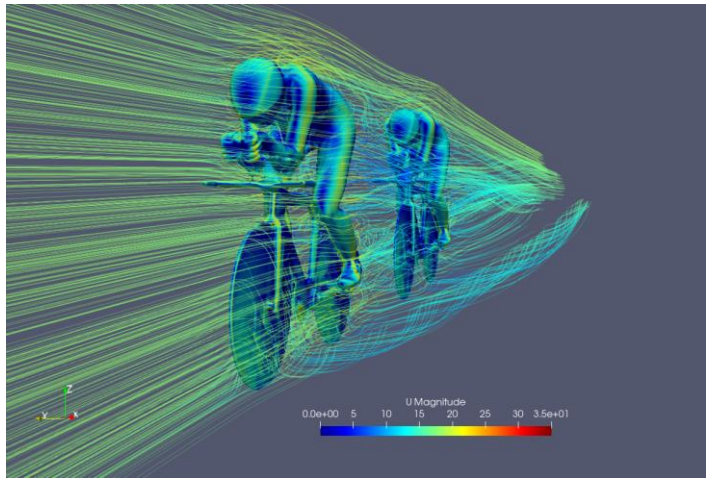
y+	1ere maille (mm)	Fx (N)	Ecart	Ecart type	Pression	Viscosité
200	20,9	1,56264	36%	0%	95%	5%
85	15	1,16975	2%	0%	93%	7%
67	9,84	1,15801	1%	0%	94%	6%
47	6,28	0,99714	13%	0%	92%	8%
27	3,07	1,02275	11%	1%	90%	10%
20	2,31	0,97780	15%	0%	91%	9%
16	1,53	1,10758	3%	1%	89%	11%
10	1,31	1,02799	10%	1%	92%	8%
6	0,644	1,17743	3%	2%	92%	8%
4	0,426	1,17227	2%	3%	93%	7%
2	0,235	1,14171	0%	3%	93%	7%
1	0,144	1,14633	0%	3%	93%	7%



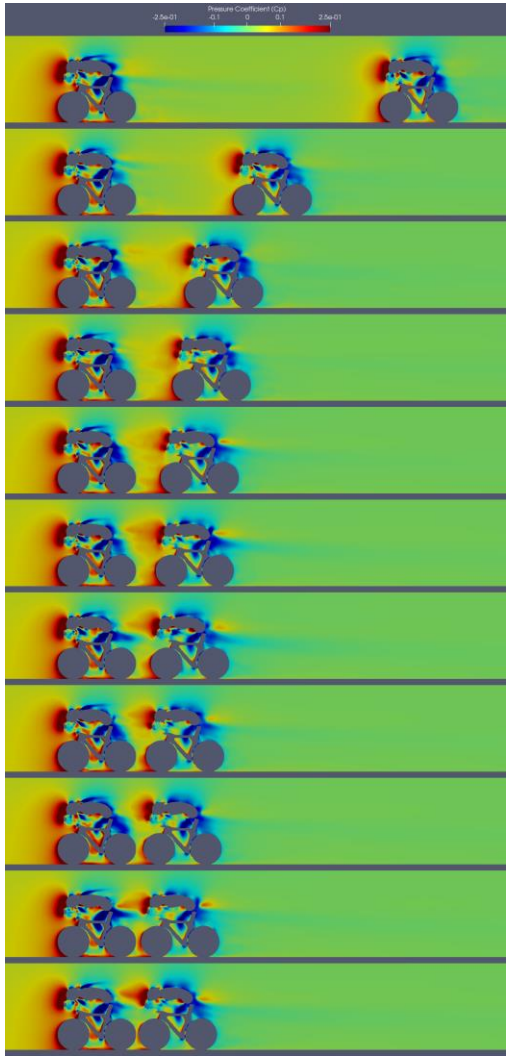
y+ = 6 OK but y+ = 2 better is if possible

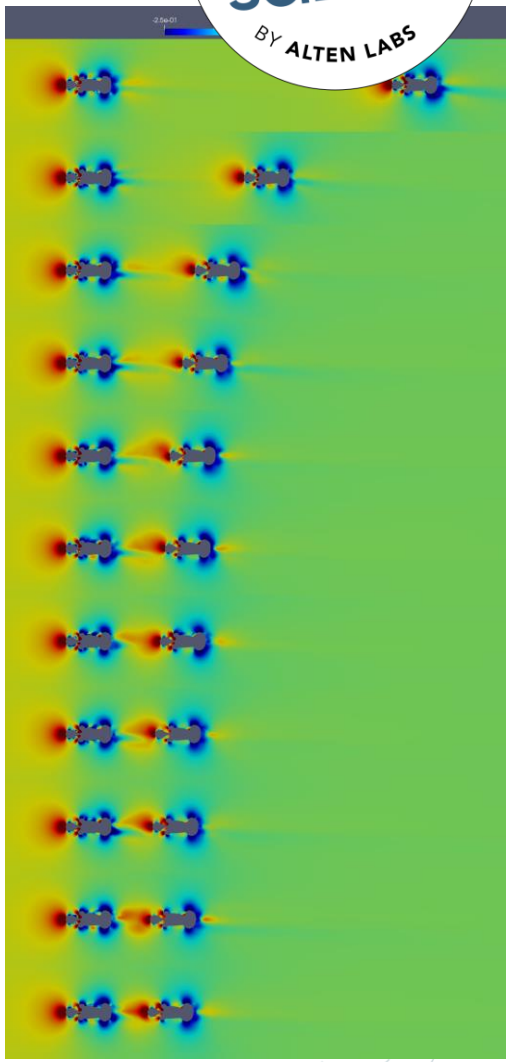
Drag on 2 cyclists



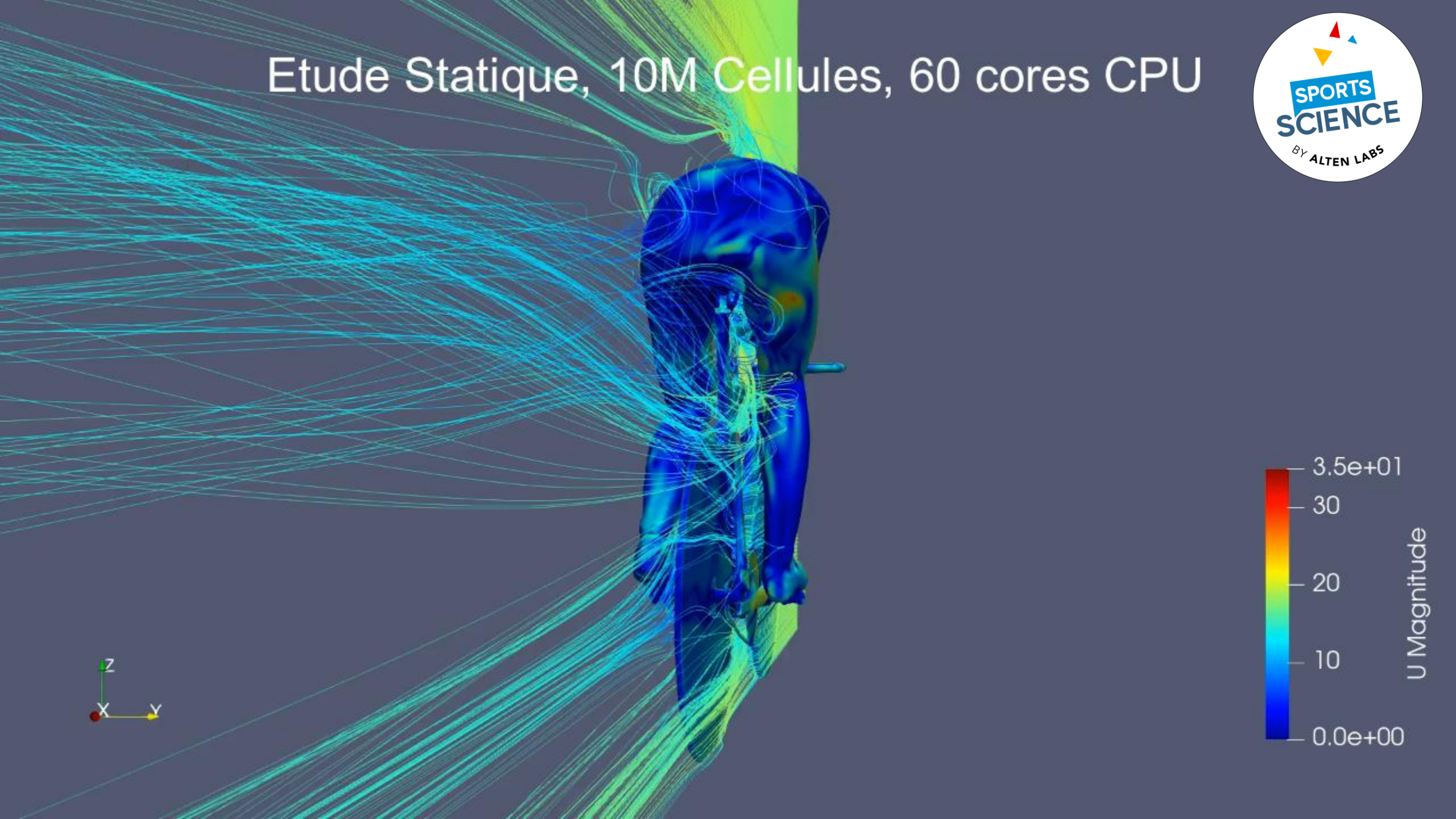


- 11 Positions
- 5cm to 5m

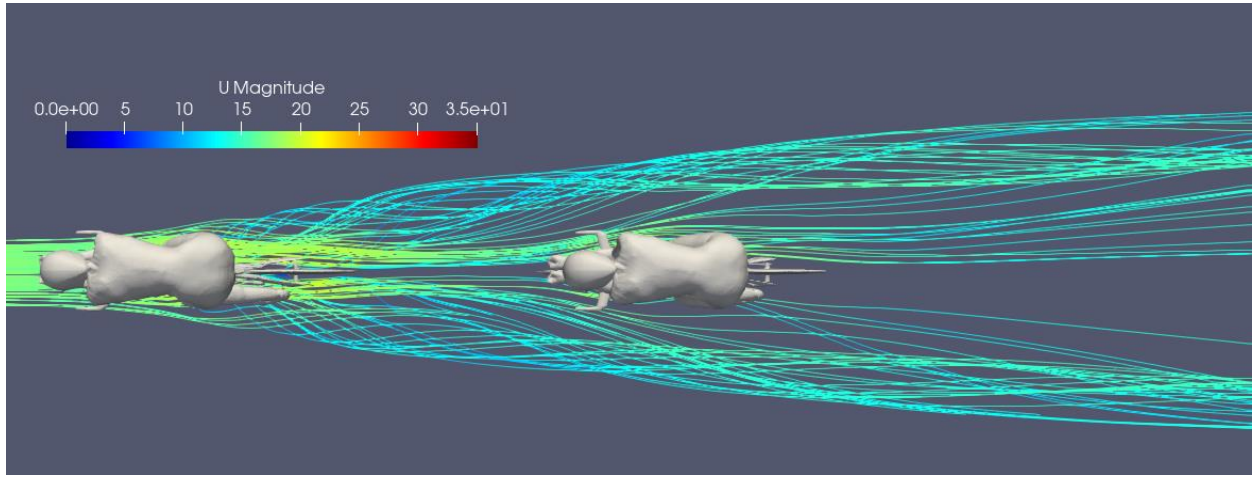


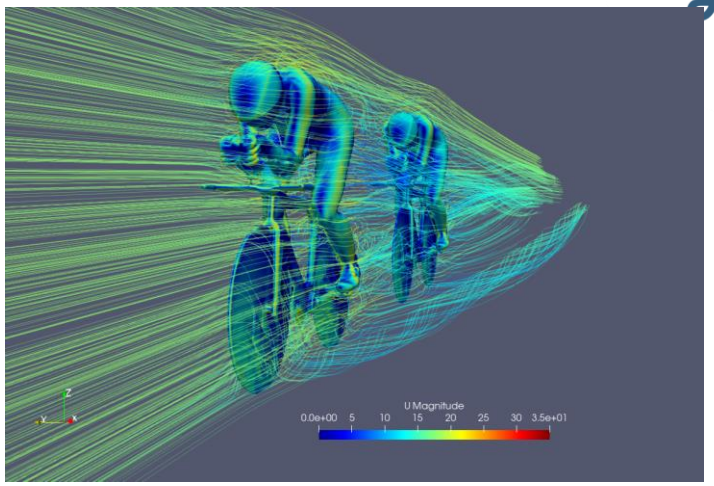


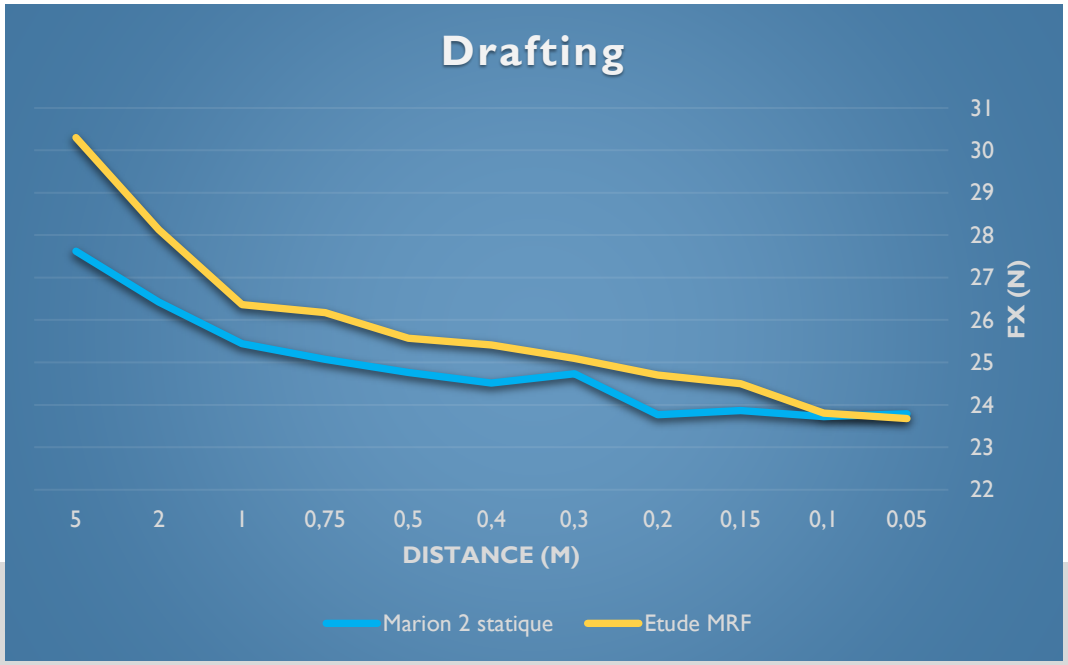
Etude Statique, 10M Cellules, 60 cores CPU

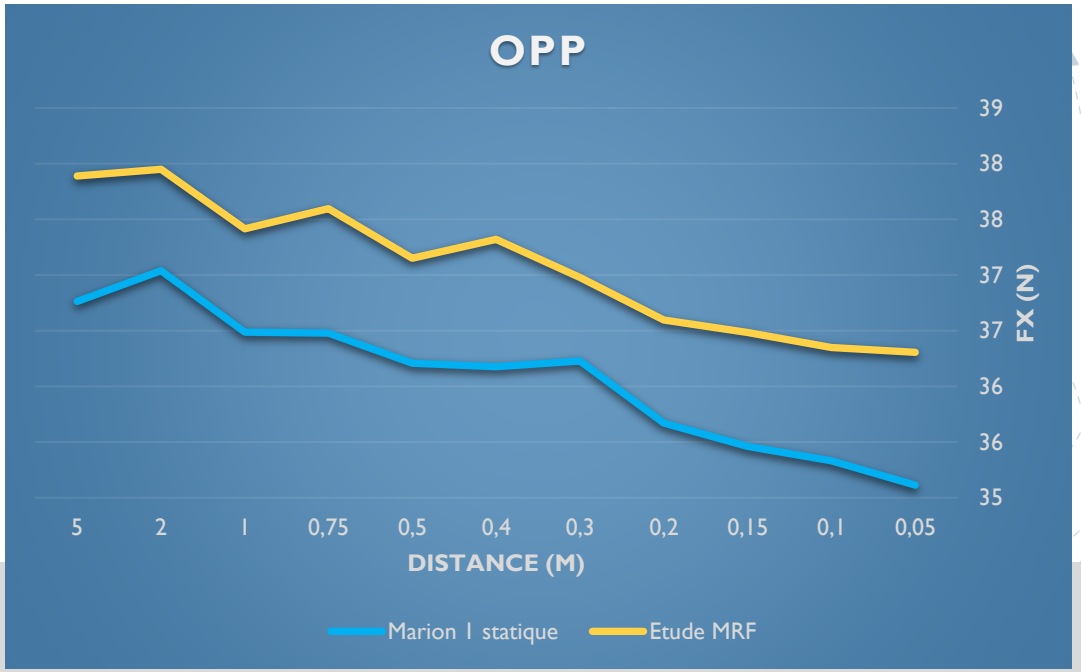


OPP static & MRF



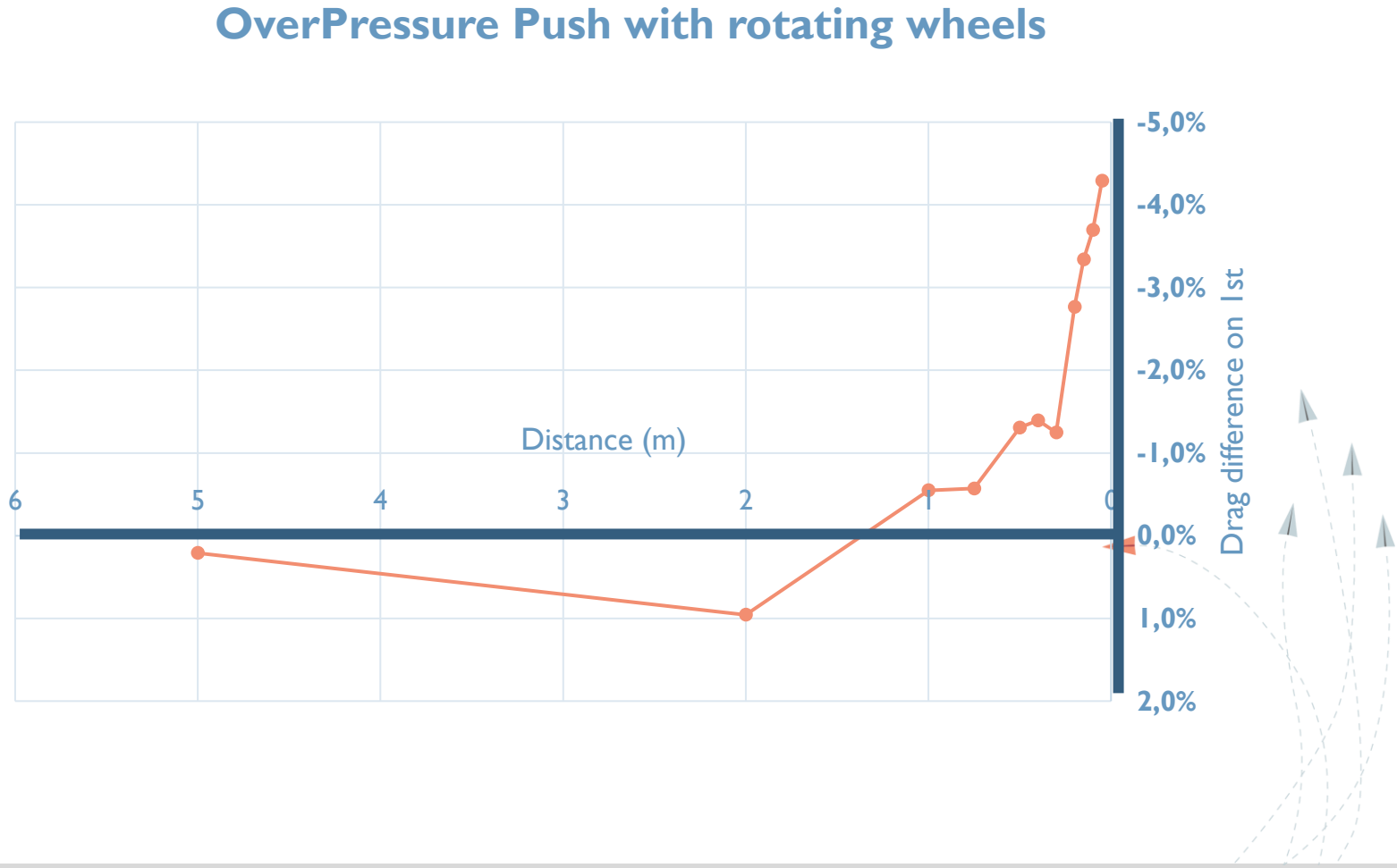


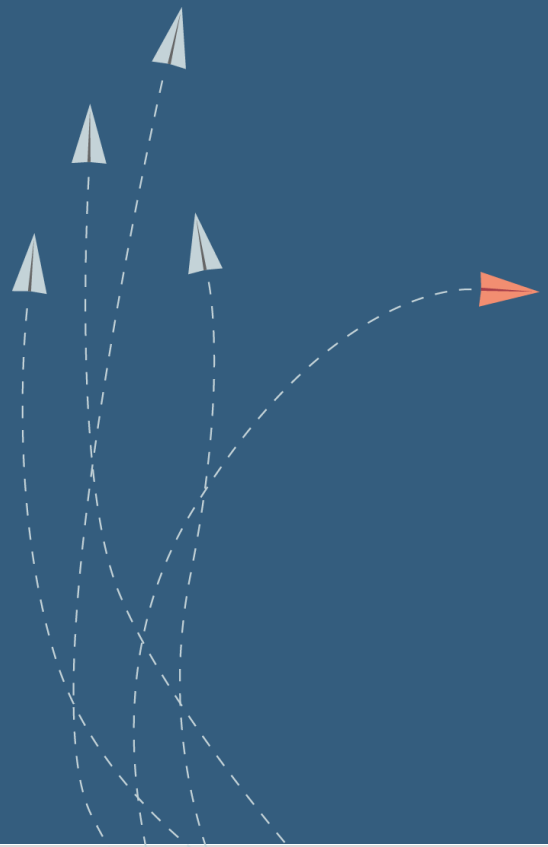




Conclusions

OPP becomes significant from 0.5m can reach up to 4-4.5% of drag reduction for the 1st cyclist



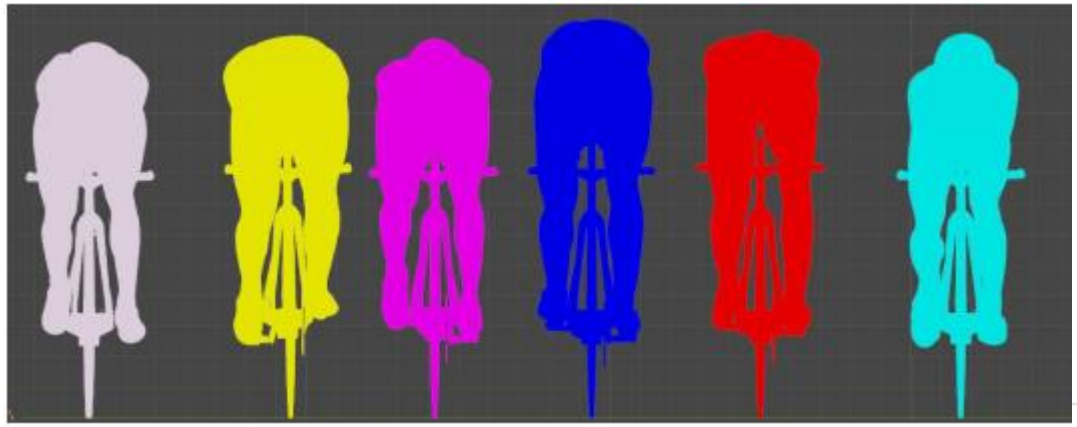


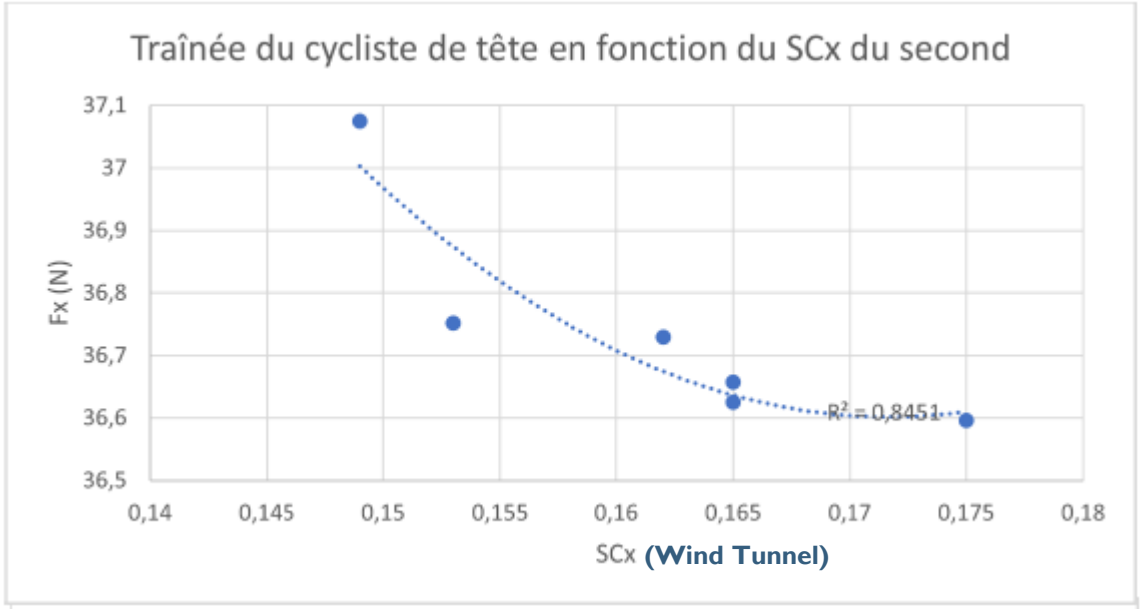
Ok, Now what ?

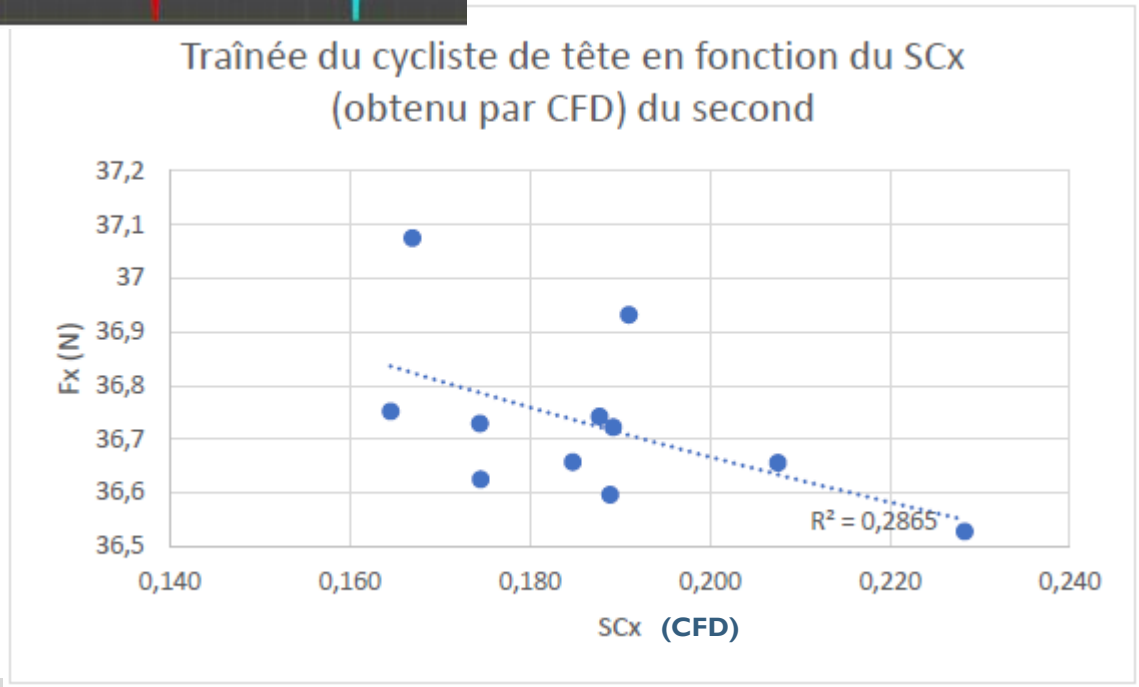
The FUN stuff !!!!!

How far are they actually ?

Influence of body shapes on OPP







Optimisation of Team Pursuit

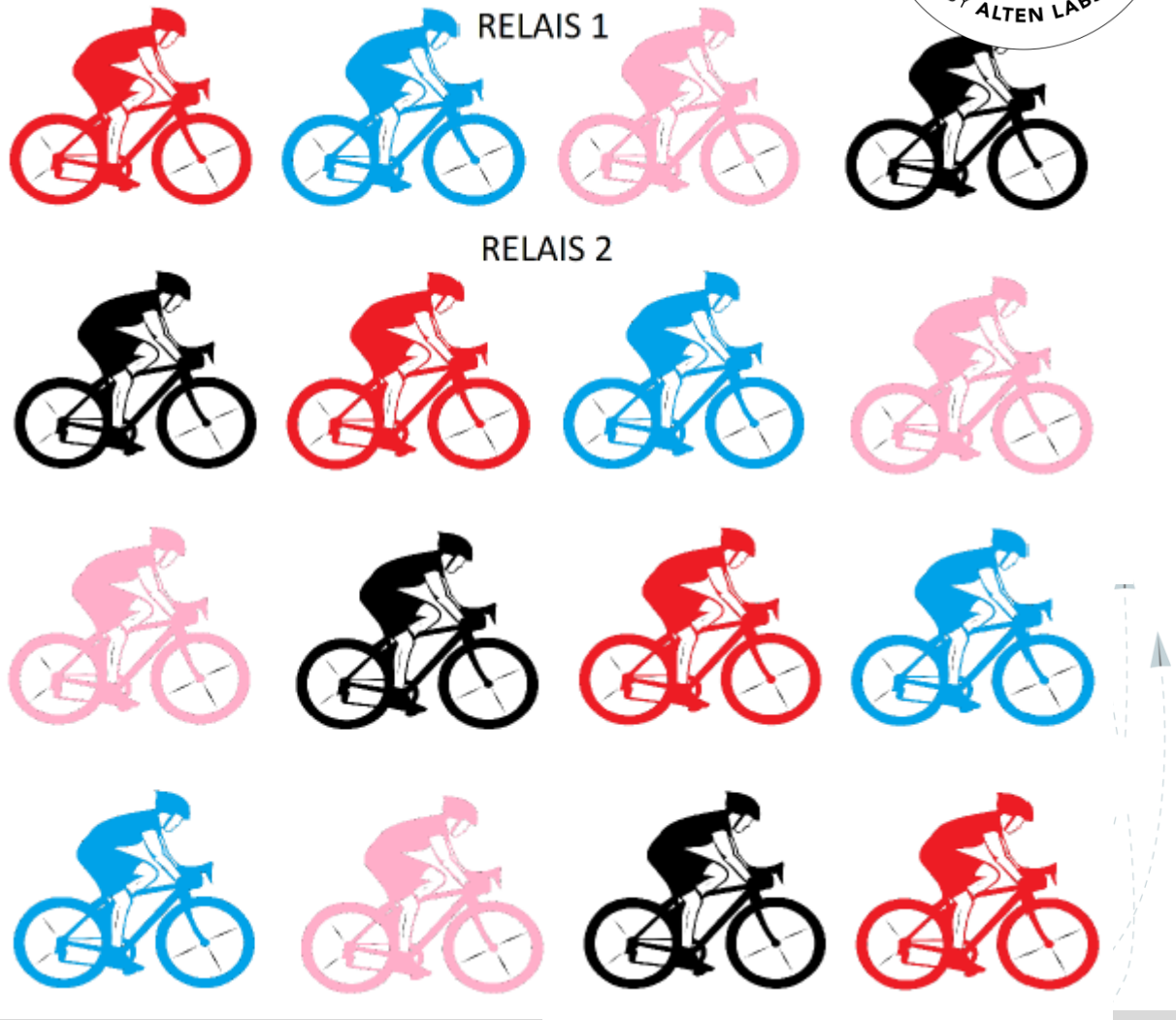
4 cyclists, rotating

6 possible starting orders, 4 rotations each

⇒ 24 configuration tested

⇒ (y+ ~5, no MRF, 100MCells)

⇒ Wheel space : 20cm



Optimisation of Team Pursuit (2)

Starting Order	Average of 4 rotations	Difference with best
1 : ex (A-B-C-D)	82.98 N	-
2 : ex (A-B-D-C)	83.99 N	1.2%
3 : ex (A-C-B-D)	84.10 N	1.3%
4 : ex (A-C-D-B)	84.45 N	1.8%
5 : ex (A-D-B-C)	85.13 N	2.6%
6 : ex (A-D-C-B)	85.56 N	3.1%

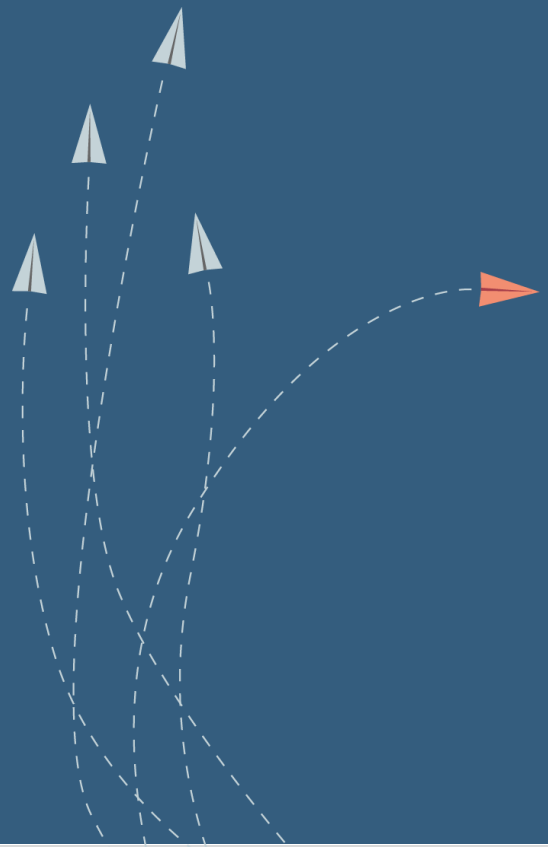
⇒ Potential impact : 4.5sec…

Thank you for your attention

Questions ?

Contacts

Sébastien RICCIARDI	Sebastien.ricciardi@alten.com
Antony COSTES	Antony.costes@alten.com
Georges SOTO-ROMERO	gsotorom@laas.fr



Appendices

B. Etude de convergence en maillage

Comme nous avons pu le voir précédemment, nous avons fait varier la taille de première maille au cours de cette étude. Plus précisément, nous avons analysé la valeur de force de traînée (Fx) obtenue pour chaque valeur de y+, défini comme suit :

$$y^+ = \frac{\rho u_\tau y_p}{\mu}$$

Avec **ρ** la masse volumique de l'air (kg/m^3), u_τ la vitesse à la paroi (m/s), **μ** la viscosité dynamique et enfin y_p la demie-hauteur de cellule, liée à la taille de première maille évoquée auparavant.

Lors de cette étude, nous faisons varier la valeur de y+ de 300 à 1, afin de balayer le spectre des lois de paroi, illustrées par la figure ci-dessous :

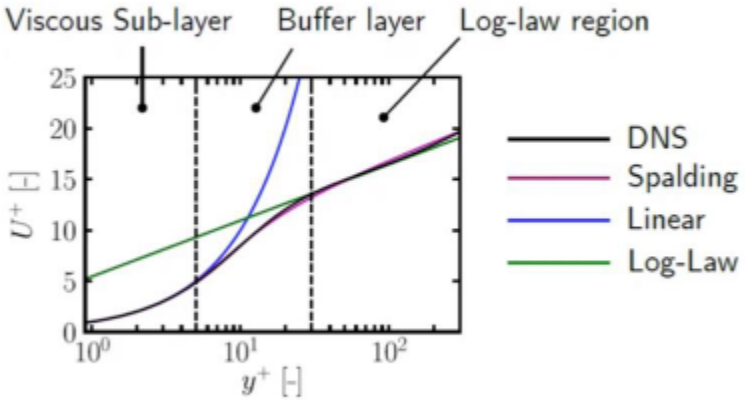


Figure 16 - Modélisation de la couche limite en fonction de y+